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Solid Index versus Impression for transferring the Position of implants in Mandibular total Edentulous Arches: A Clinical study on trueness

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***Abstract*— To evaluate the trueness of two techniques for transferring the position of implants, with respect to the angles and distances between them, in completely edentulous arches rehabilitated with 3 and 4 implants. All patients were subjected to 2 impressions techniques: solid index (SI) and conventional impression using the open tray (MC) technique. The cast models were digitized by a laboratory scanner, and the generated STL files were imported into engineering software to measure the axes of the coordinates of the implants and the distances between the implants. The Wilcoxon test was used to identify the differences between the SI and MC groups (p<0.05). The Spearman correlation coefficient was applied to identify the correlation between the coordinate axes and the distances between the implants (p<0.05). When comparing the SI and MC groups, a significant difference was observed in the x-axis of implant #1, for the arches with 3 and 4 implants (p<0.05). As for the distances, a significant difference was observed between implants 1-2 in the arches with 4 implants (p<0.05). No correlation was identified between the two dependent variables. The SI, as well as the MC, must be developed to obtain a passive adjustment framework.*

I. INTRODUCTION

The passive adjustment of implant-supported fixed total prostheses is a determining factor for their long-term success.[1-4] Biological and mechanical complications, such as progressive marginal bone loss (peri-implantitis), increase or accumulation of biofilm (mucositis), loosening of the abutment screw, fatigue fractures in the prosthetic components[5,6] or the implant, and loss of osseointegration, ,may contribute to the inadequate adjustment of the metallic infrastructure with the abutments or implant, to varying extents.[2,4]

The impression techniques and materials,[4,7] impression copings, presence or absence of splinting, as well as the splint material and the number and angulations of the implants[4,8] are factors that affect the transfer precision of the position of the implants to the mold and later to the plaster model.[4,9] This model, which is used for waxing the metal framework, may still be influenced by the operator's experience, plaster handling, and mold casting technique.[10]

In this context, several impressions techniques have been used for the construction of working models to provide a more precise clinical adjustment of the metal framework. The methods of immobilization of the copings, either by splinting with dental floss followed by acrylic resin,[3,9,10-12] addition silicone,[3] interocclusal registration materials,[3,12] type II plaster,[12] or methods involving rigid materials such as titanium bars[9] and solder index previously projected in 3D on a digitized reference model,[13] produce molds that are more accurate than those obtained by techniques without splinting. Methods for capturing the position of the implants with the solid index proved to be superior to conventional (impression) and digital methods.[13-15]

Numerous in vitro studies have evaluated the influence of impression techniques on the transfer precision of multiple implants,[3,9,10-12] as well as the accuracy and/or precision of digital versus conventional impressions from the axes of the three-dimensional plane.[16-18] However, to our knowledge, studies comparing the clinical data between the two techniques for obtaining the implant positions, using the same splinting material and abutment levels, to evaluate the axes on a three-dimensional plane, the distance between the implants, while comparing arches with four and three implants, have not been reported in the literature. In this cross-sectional clinical study, we proposed to evaluate the accuracy of two techniques for transferring the position of implants, regarding the angle and distance between the implants in total edentulous arches rehabilitated with four and three implants. The null hypothesis is that there is no difference between the solid index (SI) and the transfer impression of the position of the implants in the total edentulous arches rehabilitated with four and three implants respectively.

II. MATERIALS AND METHODS

This cross-sectional study was carried out at the Dentistry Department of the Federal University of Rio Grande do Norte (UFRN) and was approved by the institution's Ethics and Research Committee (CEP-UFRN) under protocol number 3.673.666. It included 10 and 7 patients with four and three implants, respectively, and cases of implant loss were excluded from the study.

The sample size was obtained from a previous study on the precision of different techniques for transferring implant positions. The results of the study by Papaspyridakos et al. (2011)[18] for the total 3D displacements of the axes (x, y, and z) obtained an average of 44 µm and a standard deviation of 17 µm for the technique with splinting and an average of 89 µm and standard deviation of 60 µm for the technique without splitting. A two-tailed hypothesis test with a significance level of 5% and power of 80% resulted in a sample size of 32 implants. Considering the loss of follow-up, the sample size was increased by 20%, resulting in 52 implants. Thus, in total, 61 implants were evaluated for the two dependent variables in this study.

After clinical and radiographic evaluation of the implants, all patients underwent two techniques of obtaining the implant positions: SI (solid index) and conventional impression using the open tray (MC) technique, which was performed by a single operator (Fig. 1).

To make the models corresponding to the two techniques, prior to insertion in the mouth, the copings (Neodent; Straumann) were wrapped with self-curing acrylic resin (GC Pattern resin, GC Corporation, Tokyo, Japan)[19] After polymerization of the resin, the copings were screwed onto the abutments with a torque of 10 Ncm (manufacturer's instruction). Then, the copings were splinted with metallic fragments (tips/drills for dental use) and acrylic resin was used to fix them in place.

At this time, after the resin's polymerization reaction, the copings were unscrewed to obtain the SI models, and then removed from the oral cavity to fix the analogs (Neodent, São Paulo-SP, Brazil) in the copings. This resin pattern was immersed in plaster type IV (Dentsply, Vila Gertrudes, São Paulo, Brazil),[13] and after crystallization, the copings were unscrewed from the model.

To obtain the MC plaster models, a plastic tray was used to transfer the impression of the implant positions. An access window was created to release the abutments in the mouth, and then it was loaded with dense addition silicone (Express XT, 3M, São Paulo, Brazil). The copings were wrapped with low-viscosity addition silicone (Express XT, 3M, São Paulo, Brazil) and, in sequence, the tray loaded with the dense impression material was positioned in the mouth. After the initial setting reaction of the material, the copings were unscrewed and the tray/coping set was removed from the oral cavity. The coping analogs were placed in the mold obtained, in which the space corresponding to the rim was hollowed out with artificial gingiva (Zhermack, Moema, São Paulo, Brazil) and the other anatomical structures were recorded with type IV plaster (Dentsply, Vila Gertrudes, São Paulo, Brazil).

All physical models (MC and SI) were scanned with a laboratory scanner (Zirkozahn® S600 ARTI Scan) by the same operator. For this, scan bodies for abutments (Neodent; Straumann) were screwed over the existing analogs in the models and torqued at 10 Ncm

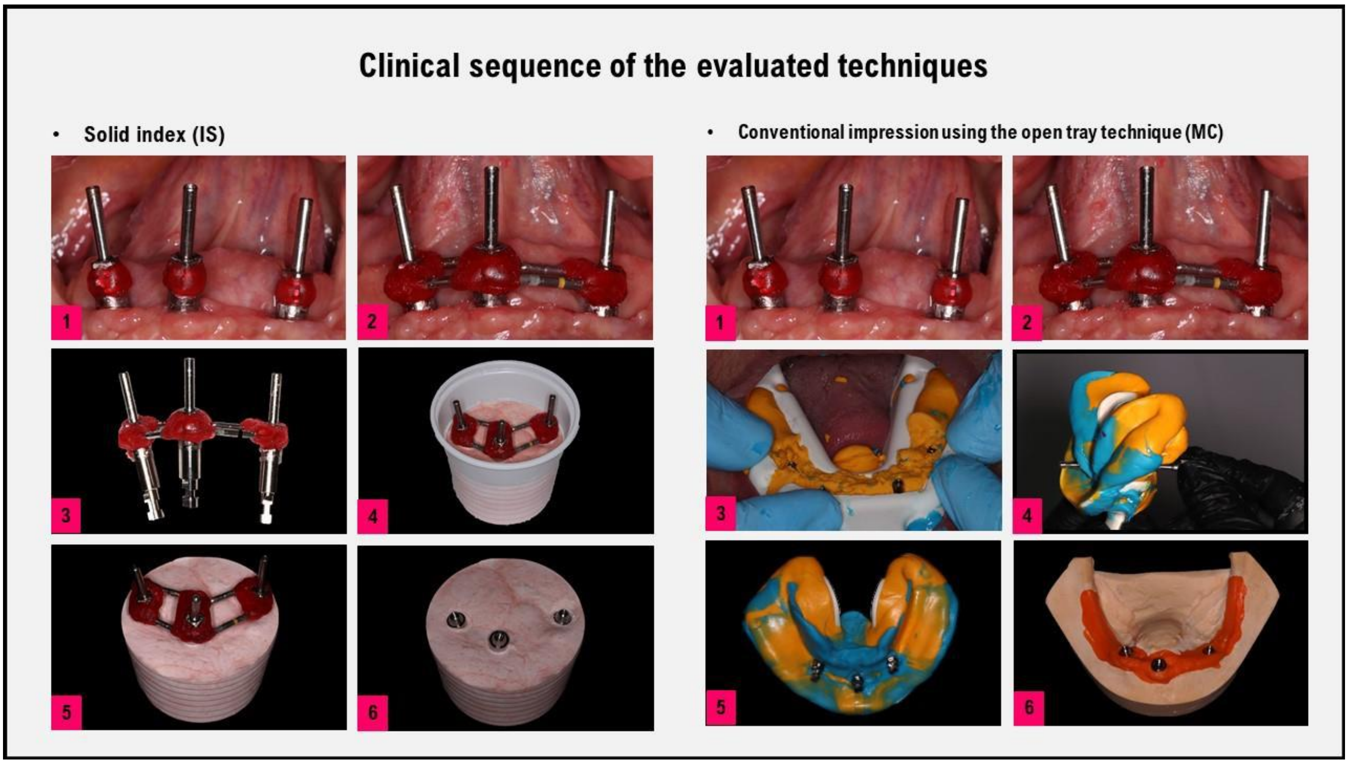

Fig. 1: Clinical sequence for performing the evaluated techniques. Index solid: (1) Impression copings positioned on abutments, (2) Copings splinted with metallic fragments, (3) Copings unscrewed and removed from the oral cavity to fix the analogs, (4) Resin pattern immersed in plaster type IV, (5) Removal of the plastic matrix, (6) Copings unscrewed from the model. Conventional impression using the open tray technique: (1) Impression copings positioned on abutments, (2) Copings splinted with metallic fragments, (3) Plastic tray loaded with dense addition silicone and the copings wrapped with low-viscosity addition silicone, (4) Tray/coping set was removed the oral cavity and the coping analogs placed in the mold, (5) Mold, (6) Cast model.

(manufacturer's instructions). Standard Tessellation Language (STL) files were stored in the scanner software used for the analysis.

Codes regarding the implant positions were standardized for the two dependent variables in this study: For cases rehabilitated with four implants, the following were considered: (1) posterior right, (2) anterior right, (3) anterior left, and (4) posterior left, and for cases with three implants, (1) posterior right, (2) median, and (3) left posterior. Thereafter, six distances (1-2, 2-3, 3-4, 1-4, 1-3, and 2-4) were measured for cases of four implants and three distances for cases with three implants (1 -2, 2-3, and 1-3). In both cases, the three axes of the coordinates (x, y, and z) of the implants were evaluated accordingly.

Thereafter, the STL files of the digitized physical models were imported into the GOM Inspect software (GOM GmbH, Germany). Initially, these were overlapped using a three-point alignment, followed by a better fit.[16] In view of the absence of a digital table in the software, the SI model was used to standardize the insertion axis of the models to be evaluated. Therefore, the MC models (real elements) were superimposed on the SI (nominal elements), and for this, the scan body inputs corresponding to positions 1 and 4 in the cases with four implants and one and three for the cases with three implants were determined as the most suitable planes for the alignment of the files.

Subsequently, cylinders were designed for each scan body and a coordinate system was defined to extract the values corresponding to the x, y, and z axes of each implant, and the end of the upper centroid of each scan body was used to trace the measurement lines between the implants at pre-established distances.

The measurements were performed three times by the same operator (H.V.M.S.), and then checked by a second independent appraiser (A.L.C.P.), at an interval of 3 days, and an average of the measurements was included for data analysis. The data were analyzed using statistical software (IBM SPSS Statistics, v22.0; IBM Corp). The descriptive analysis was based on data presented as median ($\bar{x}$) and quartiles 25 (Q^{25}) and 75 (Q^{75}). The Wilcoxon non-parametric test was used to verify the statistical difference between the SI and MC groups, as well as between the rehabilitated arches with four and three implants, assuming a significance of $p<0.05$. The Spearman correlation coefficient was applied to identify the correlation between the coordinate axes and the distances between the implants for cases with four and three implants ($p<0.05$).

III. RESULTS

To assess the reliability of the data, the interclass correlation coefficient was applied for each axis (x, y, and z) and distances between the implants were calculated accordingly (Chart 1).

Charts 1: Interclass Correlation Coefficient.

	SI	MC
Distances	1,000	1,000
Axis x	0,999	0,999
Axis y	0,995	0,994
Axis z	0,655	0,997

A total of 40 and 21 implants for the rehabilitated arches with four and three implants, respectively, were evaluated for the coordinate axes (x, y and z), totaling 61 for both the groups.

When analyzing the values corresponding to the x-axis of the arches with four implants (Table 1), a statistically significant difference for implant #1 was observed (right posterior implant), when comparing the SI group with MC ($p<0.05$). However, in the y and z axes, no statistically significant differences were observed for any of the implant positions in the arch ($p<0.05$). For the arches rehabilitated with three implants (Table 2), no statistically significant differences were identified for the y and z axes of the two groups, whereas for the x-axis, differences were observed for implant #1 and in the total median value ($p <0.05$).

Sixty and 21 distances between the implants were evaluated, respectively. For the rehabilitated arches with four and three implants, 60 and 21 distances between the implants were evaluated, totaling 81 distances for the two groups. When observing the distances measured for the cases with four implants (Table 3), the value of the total median of the MC group was greater than that of the SI, with a statistically significant difference ($p<0.05$). For the arches rehabilitated with three implants (Table 4), there was no statistically significant difference for each distance and the total value per group ($p<0.05$).

No correlations were observed (Supplementary Material) in either case (four and three implants) between the axes and distances for the implants in the SI and MC groups.

IV. DISCUSSION

Based on the results, our null hypothesis was rejected. This cross-sectional clinical study analyzed the accuracy of two techniques for transferring the implant positions, regarding the angle and distance between them in total edentulous arches rehabilitated with four and three implants. The impression for transferring the implant positions using the open tray technique (group MC) did not accurately capture the x-axis of implant #1, for cases with four and three implants, when compared to the SI group, as well as the distances between the implants for cases with four implants. No correlations were observed between the two groups for the distances and axes in cases with four and three implants.

The clinical and laboratory phases, necessary for the making of the plaster model, which are used for the closure, casting, and pressing of the implant-supported fixed total prosthesis, can affect the accuracy of transferring the orientation of the implants to the plaster due to movement of the implants and impression copings. The splinting of these is seen as a solution to minimize such movements, with a view to stabilizing them under the tightening torque to the analog of the copings that will be positioned in the mold, thus reducing the rotational freedom of the copings within the impression material.[9] In addition, the sequence of unscrewing the copings to remove the impression tray from the oral cavity can also cause minimal movements and influence the accuracy of the plaster model.[20]

Although splinting techniques have shown excellent results over the years, contrary opinions have been reported in the literature. Some problems can affect the splinting techniques, such as the fracture of the splinting material with copings,[21] because of the polymerization contraction of the acrylic resin, which is the most commonly used material. The solution would be to section the splint and then reconnect it with a small amount of the same material, after a specific time interval, as evidenced by a previous study,[22] which showed that 80% of the polymerization shrinkage occurred in the first 17 minutes.

The standardization of the two techniques of impression from splintering with metallic fragments made excellent results possible, once the evaluated groups presented minimal differences. Previous studies have evaluated the use of metal bars to immobilize copings. Shankar & Doddamani (2020),[9] showed that the immobilization methods using the direct technique with metallic splinting, followed by welding in the mouth, produced the most accurate molds, in comparison to the direct technique of splinting with dental floss and acrylic resin and direct technique without splinting.

Table 1: Median values (Q^{25}/Q^{75}) of the axes of the coordinates of the implants for cases with four implants.

IMP	n	x			y			z		
		SI	MC	*p*	SI	MC	*p*	SI	MC	*p*
1	10	5,81100 2,75800/11,80350	4,73800 3,31050/10,29250	**0,006***	7,93600 4,77400/10,55000	7,11300 4,52950/11,20500	0,653	80,09800 75,47750/83,15600	79,35400 72,85100/82,82850	0,246
2	10	3,07500 1,87750/6,99800	3,66600 1,84400/6,75350	0,868	6,32800 4,64750/10,56200	6,69000 3,15500/10,74800	0,906	79,74900 77,48200/83,93850	80,00700 76,90500/85,30400	0,795
3	10	3,61500 1,43500/6,99200	3,64300 2,03750/7,85300	0,210	6,31500 3,05200/10,35050	5,38500 3,48400/10,00300	0,981	80,57000 76,70550/83,97300	81,62200 76,40800/85,41700	0,943
4	10	4,12800 3,00875/9,74825	4,63100 1,86525/10,02725	0,646	5,14350 2,96450/9,36075	4,10900 1,76050/7,62925	0,333	81,95000 73,11700/84,10250	82,79900 73,47250/85,30500	0,508
All	40	3,86400 2,32050/8,05700	4,53300 2,16100/8,30400	0,051	6,32800 4,02550/9,70350	6,69000 3,41650/10,59450	0,906	80,56800 76,65900/83,50250	80,24200 75,80750/85,03200	0,638

Q^{25}: Quartile 25; Q^{75}: Quartile 75; IMP: implant; 1: right posterior implant; 2: right anterior implant; 3: left anterior implant; 4: left posterior implant; SI: solid index; MC: conventional impression using the open tray technique.

Table 2: Median values (Q^{25}/Q^{75}) of the axes of the coordinates of the implants for cases with three implants.

IMP	n	x			y			z		
		SI	MC	*p*	SI	MC	*p*	SI	MC	*p*
1	7	6,410 3,341-15,082	8,190 5,482-17,494	**0,028***	7,936 4,707-14,169	6,855 3,311-11,231	0,612	81,349 69,061-85,184	79,354 66,564-83,288	0,091
2	7	4,773 3,075-10,003	6,424 3,666-11,579	0,499	4,773 3,075-10,033	6,690 3,321-8,130	0,866	79,749 77,619-83,804	80,007 76,571-82,014	0,091
3	7	3,303 1,027-7,882	3,643 2,620-8,085	0,176	5,935 2,824-6,340	3,966 3,456-7,486	0,866	80,570 73,741-86,719	85,025 75,727-85,355	1,000
All	21	4,738 2,922-9,463	6,424 3,216-10,368	**0,006***	5,935 4,395-7,373	6,690 3,416-9,550	0,741	80,570 74,936-84,431	80,242 76,023-85,123	0,092

Q^{25}: Quartile 25; Q^{75}: Quartile 75; IMP: implant; 1: right posterior implant; 2: median implant; 3: left posterior implant; SI: solid index; MC: conventional impression using the open tray technique.

Table 3: Distances between implants for cases with four implants (Median - Q^{25}/Q^{75}).

Distances	n	SI	MC	*p*
1-2	10	13,52500 92,6850/16,19500	13,43100 9,44300/16,67100	**0,022***
2-3	10	15,93800 14,13000/18,93550	16,13900 12,7400/18,83950	0,653
3-4	10	10,97000 9,6965/29,36550	11,16500 9,52300/29,30950	0,136
1-4	10	31,52700 30,44100/32,78675	31,68150 30339,25/32743,50	0,386
1-3	10	24,79850 22,67625/26,97425	24,84900 22,91575/26,17350	0,241
2-4	10	23,93600 21,41950/27,42500	23,95250 21,61425/27,04450	0,445
All	60	19,04300 12,88750/27,52800	18,95900 13,10850/27,39950	**0,003***

Q^{25}: Quartile 25; Q^{75}: Quartile 75; 1: right posterior implant; 2: right anterior implant; 3: left anterior implant; 4: left posterior implant; SI: solid index; MC: conventional impression using the open tray technique.

Table 4: Distances between implants for cases with three implants (Median - Q^{25}/Q^{75}).

Distances	n	SI	MC	*p*
1-2	7	17,128 15,903 – 28,419	17,106 16,462 – 28,435	0,058
2-3	7	16,521 15,753-16,817	16,779 16,361-17,102	0,091
1-3	7	16,654 15,038-19,043	16,630 15,130-18,959	0,866
All	21	29,874 27,982-30,298	29,841 29,093-30,296	0,176

Q^{25}: Quartile 25; Q^{75}: Quartile 75; 1: right posterior implant; 2: median implant; 3: left posterior implant; SI: solid index; MC: conventional impression using the open tray technique.

Del Acqua et al. (2010)23 showed that the working model made from the splinting of copings with metal bars can be the most accurate, in view of the stiffness of the metal in withstanding the distortion forces. Although the authors carried out splinting with metal bars without the use of acrylic resin, as was done in the present study, the fragments were joined to the copings with a small amount of resin at the ends, just enough to keep them stabilized, freeing them from possible failures that may be associated with the section and joining method, as well as the polymerization reaction of the resin.

When evaluating the coordinate axes (x, y, and z), a statistically significant difference for the x-axis of implant #1 in the rehabilitated arches with four and three implants was observed. This difference in the x-axis was reported in previous studies that evaluated impressions performed with and without splinting.[18,24,25] Papaspyridakos et al. (2011),[18] also showed that when evaluating the effect of implant position, it was observed that the x-axis of the posterior implants in the mandible, when the impression was obtained by splinting, presented the greatest deviation, followed by the z and y axes. In view of these previous findings, which are in agreement with the results of this study, another study also pointed out that changes in the x-axis, which corresponds to the horizontal plane, would indicate the construction of smaller metallic infrastructures, that is, with a probable vertical marginal mismatch, or posterior inclination of the implants towards the palate or floor.[26] Therefore, the use of the SI model is even more appropriate than the MC model for the manufacture of metallic infrastructures.

The transfer technique from direct impression did not accurately capture the distances between the implants for the arches with four implants, when compared to the solid index. For the arches with three implants, the impression technique did not influence the results. Studies that evaluated the distances between implants, comparing splinting techniques or conventional impression methods, were unknown by the authors of this study. Rech-Ortega et al. (2019),[27] compared a conventional technique (elastomeric impression material) and a digital one, based on a master model with six implant analogs. The authors concluded that in clinical situations with more than three implants, the conventional method was more accurate than the digital method, while for cases with four implants, the digital method was the most suitable. Therefore, we justify our results for the cases with three and four implants in terms of the distances between the implants. The statistically significant differences found in the distance between the right posterior implant and the right anterior implant (#1-2) for cases with four implants reflects the changes found in the right posterior implant (#1) on the x-axis for the MC group.

The distribution of the implants preserving the maintenance area of the polygon supporting the future prosthesis,[28] contributed to the absence of correlation between the coordinate axes and the distances between the implants, for the arches rehabilitated with four and three implants. Although we are not aware of studies that correlate the number of implants with axes and distances (the opposite also applies), we emphasize that through a negative correlation, that is, as the axes increase, the distance decreases; if the plaster model that presented if this result was used to design a metallic infrastructure, it would probably present a visible vertical and/or horizontal marginal mismatch.

In view of the results, the present study showed that when comparing two techniques for transferring the position of the implants, the plaster model obtained by conventional impression using the open tray technique should be used to obtain information about the soft tissues. However, a solid index must also be developed to obtain information regarding the passive metal framework. Additionally, we compared two numbers of implants, four and three, showing that a reduction in the number of implants made the rehabilitation process more accessible to the population, owing to the reduction in the final cost of treatment.

The limitations of this study included the absence of other splinting materials, impression techniques, and types of implants. Future research should be conducted to include greater numbers of dependent variables and provide clinical responses to simplify the dental treatment.

V. CONCLUSION

The fabrication of the plaster model through MC using the open tray technique, compared to that of the SI, presented difficulties in capturing the x-axis for cases with four and three implants, but did not exhibit significant differences for the y and z axes. The number of implants influenced the record of the distances, showing that there was no difference between the MC and SI groups for the arches with three implants; however, it did not influence the correlation of the axes with the distances. Therefore, considering the conventional workflow, in addition to the MC plaster model, which provided soft tissue details that are necessary for the laboratory-based steps in the design of the metal framework and veneering the prosthesis, a solid index must be recorded to obtain sufficient details for designing the passive metal framework.

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